If the condition of step S22 is negative, the control circuitry returns to step S20 to obtain updated data for continued monitoring operations.

If the condition of step S24 is affirmative, the control circuitry proceeds to a step S24 to count the desired delay period. The delay period may be randomly calculated, otherwise varied, or fixed. Proceeding from step S22 to step S24 corresponds to the state of the power management device changing from state 2 to state 3.

Following counting of the delay period, the control circuitry operates to restore the load at a step S26 wherein the amount of electrical energy applied to the respective load may be increased.

As described above with respect to FIG. 1, power management system 15 may be implemented using a plurality of power management devices 16 in the illustrated exemplary configuration. Power management system 15 may be considered as system for managing operations of power distribution system 10 by controlling an amount of electrical energy consumed using attached loads 18. Operations of power management system 15 may be utilized to control an electrical characteristic of electrical energy of electrical power distribution system 10 if implemented using a sufficient number of power management devices 16, or a sufficient amount of an entirety of the load coupled with the electrical power distribution system 10 is controlled via devices 16. For example, it is believed that control of approximately 3% of the load or more of a system 10 may provide perceptible changes in system operation.

Exemplary power management devices 16 described herein are configured to monitor system frequency of electrical energy of the power distribution system 10 and to implement power management operations responsive to the monitoring. If provided in sufficient quantity, the power management devices 16 of system 15 can be used to control an electrical characteristic of the electrical energy. In the described example, power management devices 16 automatically implement load shedding operations responsive to the system frequency sufficiently deviating from a desired nominal frequency. If used in sufficient quantity, the aggregate effect of load-shedding operations of the devices 16 may automatically cause the system frequency to return within an acceptable range of deviation of the nominal system frequency. As mentioned previously, deviation of system frequency from the nominal system frequency represents disparities between electrical energy generation and consumption. If electrical energy consumption outweighs production, the system frequency drops relative to the desired nominal frequency. Accordingly, automatically shedding load using devices 16 responsive to system frequency monitoring operations reduces the disparity of consumption to generation at a given moment in time, and the system frequency begins to return to an acceptable range without alteration of operations at the supply 12.

As mentioned above, the power management devices 16 are configured according to a plurality of defined rules to implement load shedding and restoration operations in the illustrated examples. The described embodiments provide rules which control shedding and restoration of loads responsive to monitoring of the electrical energy of the power distribution system 10. As described above, the exemplary rules of the devices 16 reduce or cease application of electrical energy to respective loads 18 responsive to an electrical characteristic of the electrical energy triggering respective threshold values of the devices 16.

If a sufficient number of devices 16 configured according to the exemplary rules described herein are utilized, emergent behavior of the system 15 results wherein the devices 16 conforming to well-defined common rules change the aggregate group behavior of the devices 16 acting together (e.g., change the behavior of the system 10 corresponding to a change in the electrical characteristic of the electrical energy within the system 10) and individual devices 16 are autonomous and oblivious to goals of the system 15 in one arrangement.

Provision of the upper bounding value and the lower bounding value define a desired operating range of the power distribution system 10 for the respective electrical characteristic being monitored. Operation of a sufficient number of the power management devices 16 of system 15 configured with the upper and lower bounding values may maintain operations of the electrical power distribution system 10 within the desired operating range.

If a sufficient number of devices 16 are utilized in a system 10, it is possible according to additional aspects to determine or approximate the magnitude of a deficit of electrical energy production (also referred to as unserved load) at moments in time using system frequency information. For example, if devices 16 are associated with loads 18 having known amounts of power consumption (and it is also known at what approximate values of the system frequency wherein load shed operations are implemented by devices 16), then it is possible to approximate an amount of electrical energy deficit at moments in time corresponding to the system frequency. In other words, if the system frequency is at a given value wherein it is known that a number of devices 16 and associated loads 18 are in the shed mode state of operation due to the respective range of trigger thresholds (the number of loads in shed mode are determined by the system frequency and the respective trigger thresholds, and the amount of associated electrical energy consumed or shed by the loads is known), then it is possible to calculate the amount of electrical energy deficient with respect to the system 10. In addition, using the current price for the electrical energy at the moment in time, as well as a supply and demand curve, it is possible to approximate or estimate the price of the electrical energy if the amount of the deficit is supplied by increasing the output of supply 12. Accordingly, system frequency may be utilized to determine or approximate an amount of unserved load at moments in time and approximate price information if the unserved load were to be served by increasing the electrical energy output of supply 12.

As described above, exemplary aspects of the power management system 15 described herein provide power management devices 16 which change respective thresholds to create an equitable distribution of inconvenience (e.g., load shedding) to the users. Further, utilization of a sufficient number of devices 16 configured according to exemplary rules described herein results in emergent behavior.

According to additional aspects, power management system 15 comprising devices 16 may be utilized to avoid or minimize power flow oscillations within electrical power distribution system 10. More specifically, operational problems may sometime arise when the conditions of supply and demand dictate power transfers over an inadequate transmission corridor of system 10. In such an exemplary situation, unstable transfers of electrical power from one or more generating unit in a geographic region of system 10 to another set of generators in a separate geographic region may occur. These unstable transfers of power manifest themselves in the form of oscillations. The phenomenon is often called dynamic instability or small-signal instability. This form of instability can cause system operators to limit the capacity of